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TECHNICAL REPORT

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THE USE OF AN INFRARED RADIOMETRIC MICROSCOPE IN THE NONDESTRUCTIVE DETERMINATION OF FLEXIBLE PACKAGE SEAL DEFECTS

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FOREWORD

The work covered by this report was performed under Project 1J624101D552, 6214101A, Packaging Exploratory Development, Task 02 - Design of Flexible Packaging Systems.

Flexible packaging offers significant logistic advantages, and extension of these techniques to many military applications is highly desirable. Experience with such potential applications as thermoprocessed and irradiated foods has revealed that the number of defective seals in packaging is undesirably high. A nondestructive, relatively rapid method for detecting seal defects would be an indispensable tool in improving flexible packages and for use in quality control. The infrared radiometric procedure reported here shows excellent promise to fill this need.

The cooperation of the Barnes Engineering Company, Stamford, Connecticut, during the course of the project is gratefully acknowledged.

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ABSTRACT

Infrared radiometry, whereby changes in heat conduction through the seal thickness and the resulting effect on the thermal radiation characteristics of the opposing seal surface are measured by an infrared radiometric microscope, has been used to detect significant defects in flexible package seals. Sample manipulation techniques and measurement parameters have been established to the extent that occluded matter such as single sugar crystals, 0.5-milligram amounts of meat fibers, single fruit and vegetable fibers and traces of moisture, as well as significant seal wrinkles, and the presence of small voids (90 to 100 microns in diameter) can be positively detected.

The method is applicable to laboratory and commercial-type seals formed by a hot bar against an unheated rubber anvil. Poor results were obtained with ultrasonic seals and inconclusive results with dual-heated element sealers.

I. INTRODUCTION.

The use of flexible packaging materials for thermoprocessed foods[1], where pathogenic microbial recontamination through package defects could occur, has magnified the need for rapid, nondestructive, defect detection techniques. Such a package is shown in Figure 1. Additionally, inspections of packages of thermoprocessed foods from test production runs have revealed two categories of defects: perforations on the body of the pouch, and defective seals. Seal defects include wrinkles, voids, and occluded matter. The seal defect site may or may not constitute a leak at the time of inspection.

Examination of gross seal defects by measuring variations in the thermal radiation characteristics of seal areas caused by occluded matter retarding thermal conductivity through the seal thickness showed promise. Therefore, further studies were initiated. The objective of these studies, reported here, was to establish the feasibility of using infrared radiometry to detect minute representative seal defects.

II. APPARATUS.

The apparatus consisted of three main components: the infrared radiometric microscope with associated control unit and X-Y recorder; a narrow beam flameless torch for the pinpoint heat source; and a moving carriage to hold and pass the seal between the heat source and the infrared radiometric microscope. Figure 2 shows schematically the apparatus as used during the test runs. Figure 3 is presented to indicate the critical distances of the scanning system components relative to the seal area.

Investigated were the magnitude of impedance to heat-flow through the seal thickness caused by defects, and the adequacy of the infrared microscope in detecting the resultant variations in surface temperatures on the opposite seal surface. A stream of hot air was directed at one side of the seal area and the I-R microscope was directed at the other side.

The infrared radiometric microscope used in these studies was the Model RM-2B manufactured by the Barnes Engineering Company and is shown in Figure 4. This instrument utilizes a germanium hyper-immersed thermistor bolometer detector along with the necessary optics and electronic controls to measure radiance and therefore, the temperature of small spots of known emissivity. The principles and theory of operation have

Figure 1. Flexible package showing construction (shown with similar canned product).

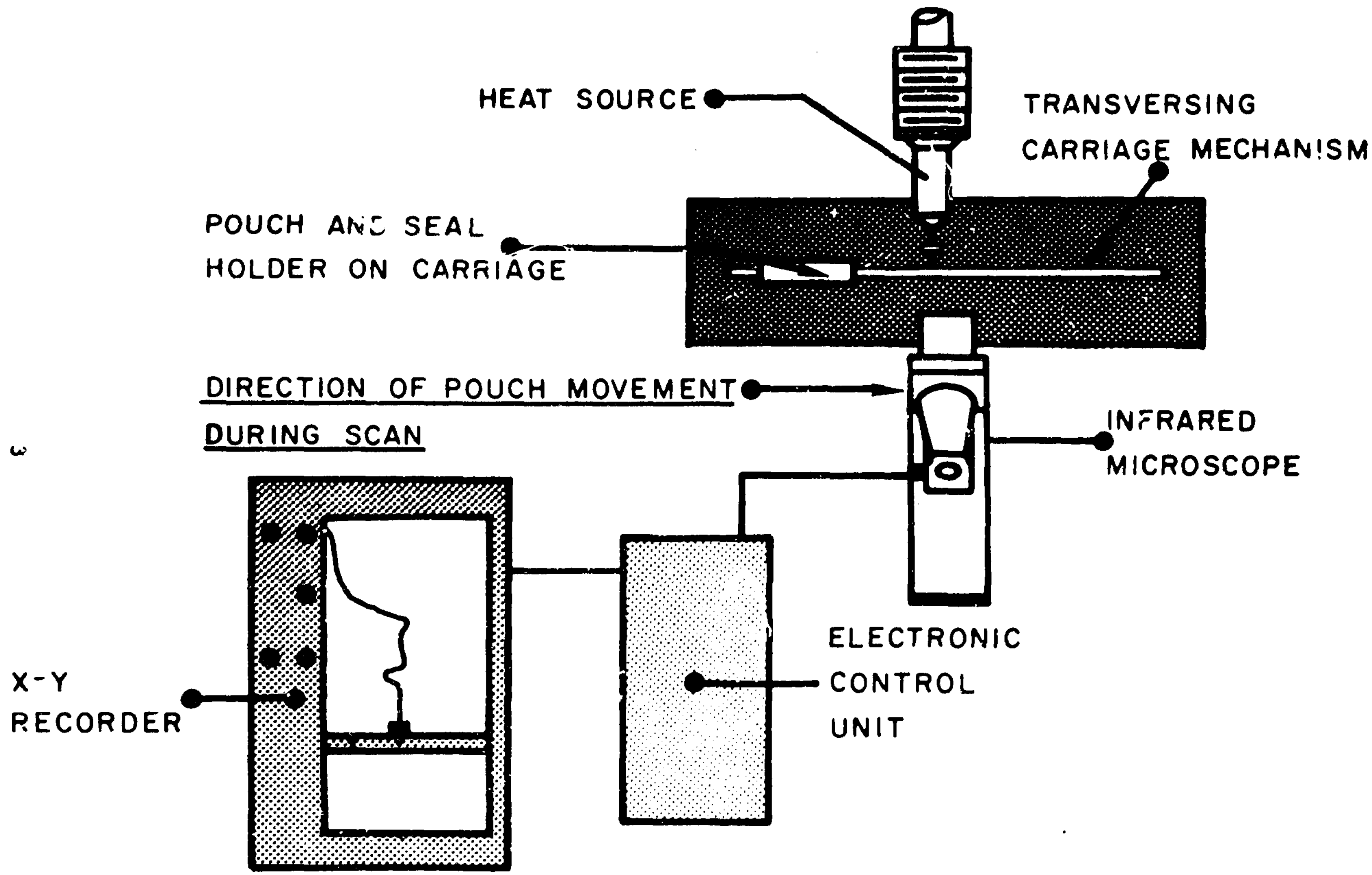

Figure 2. (Top View) Schematic Drawing of Infrared Seal Scanning Apparatus.

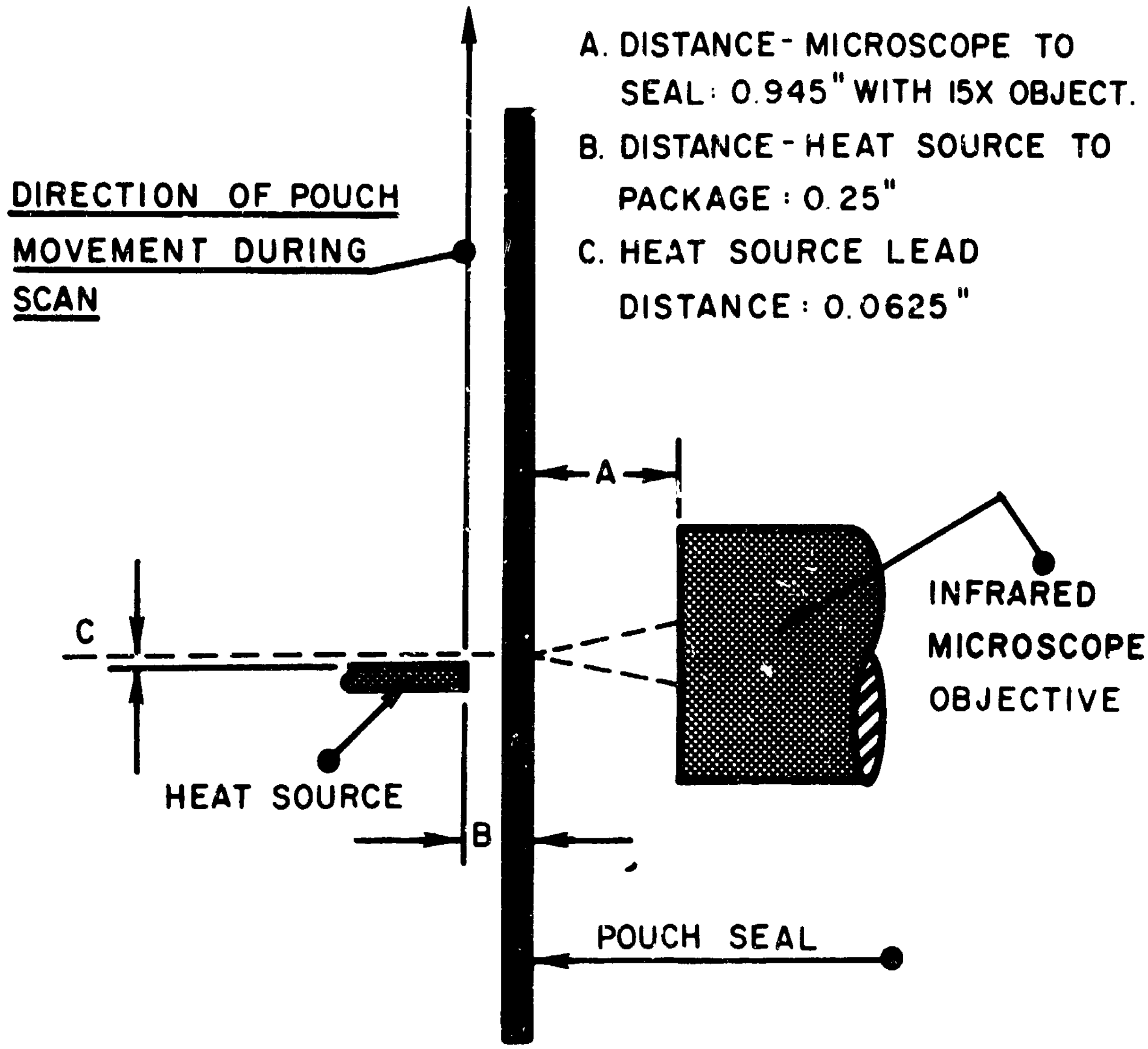

Figure 3. Schematic Drawing of Infrared Scanning Apparatus Close-up To Indicate Critical Distances.

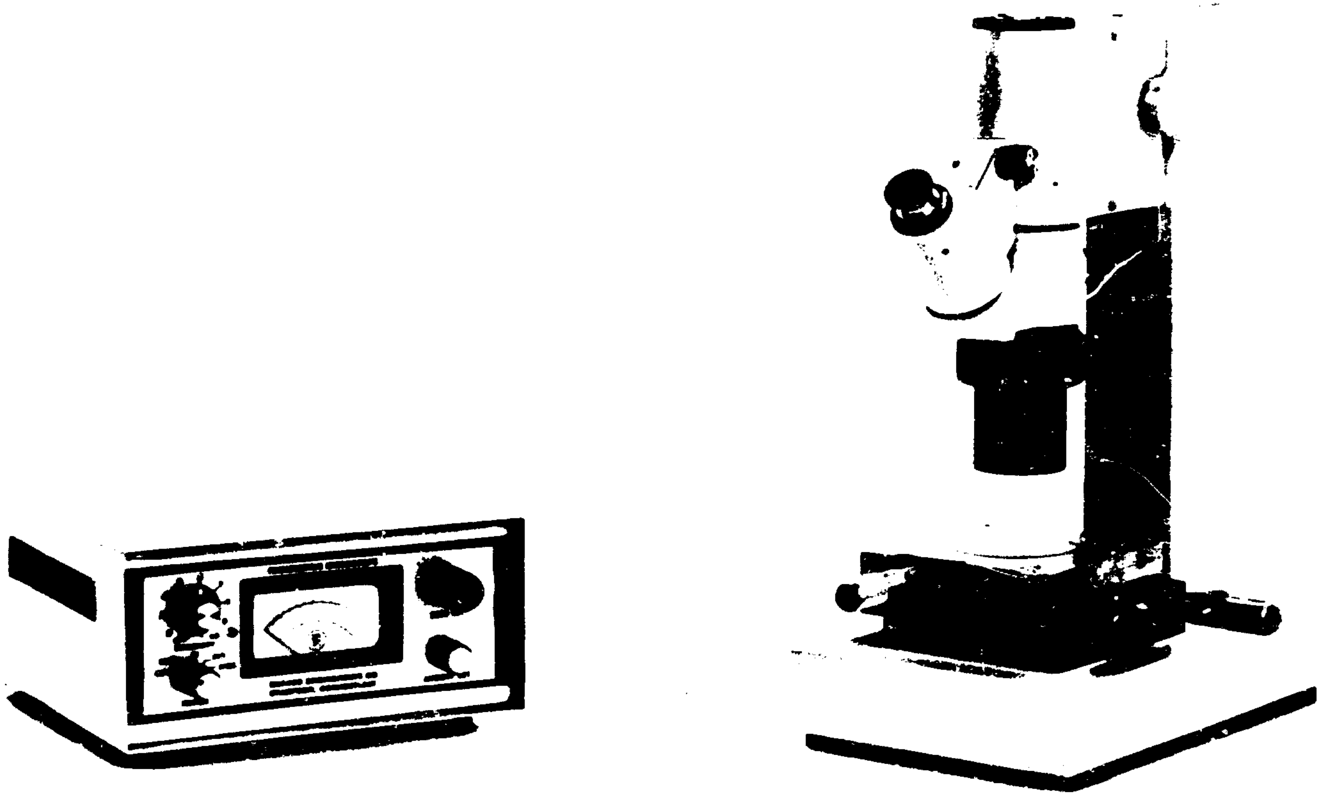

Figure 4. Infrared radiometric microscope.

been discussed by McIntosh and Yoder[2] and by Stemfill and Yoder[3]. The advantages of the instrument for detecting the relatively minute defects that can occur in seals (assuming adequate sensitivity) were that the instrument was remote, rapid in response, and did not disturb the target surface.

The rated temperature resolution of the instrument is 0.5° C. on a target of unit emissivity with the instrument bandwidth set at 1 cps. Both specimen temperature and overall system bandwidth affect temperature resolution[4].

The output of the instrument can be read directly as temperature on a temperature scale, or, for this study where changes rather than absolute values were of primary interest, as millivolts. Both Oscilloscope and X-Y recorder outputs were used; both gave useful information. The X-Y recorder, because of the permanent record, was preferred.

A 15X objective lens was used during this study. The nominal spot size on the target at the working distance of 0.95-inch is 0.0023-inch. Variations in spot size up to 0.25 inch were tried with some indication that a wider scanning band can be used without sacrificing detectability.

The pin-point source of heat was a Henes Manufacturing Company Model FT-200 flameless torch fitted with a 0.125-inch diameter nozzle. See Figure 5. Both air flow and temperature can be varied. Initial trials showed no advantage in increasing the air flow above the minimum 2 cu. ft./hr. rate; therefore, air flow was kept constant during all subsequent runs. The hot air temperature (as measured 0.25 inch from the nozzle top) was varied from 67° to 187° C. for various scans. Seal surface temperatures detected by the microscope ranged from 36° to 60° C.

The transversing carriage was constructed by the Barnes Engineering Company and was designed to move an object back and forth at a constant speed. The maximum constant speed attainable was 1.14 inch per second.

To create and maintain a flat seal surface so that a constant distance between the heat source and seal, and between the I-R microscope and seal, could be maintained during each scan, a simple holder was constructed. The holder consisted of two aluminum plates with coinciding 1/2-inch slots cut across near the top to expose the seal. Also, rectangular areas were cut from the center of the plates to accommodate the bulge of filled pouches. The two plates with the package in between were clamped together with ordinary binder clips. This assembly was in turn clamped to the pedestal of the transversing carriage.

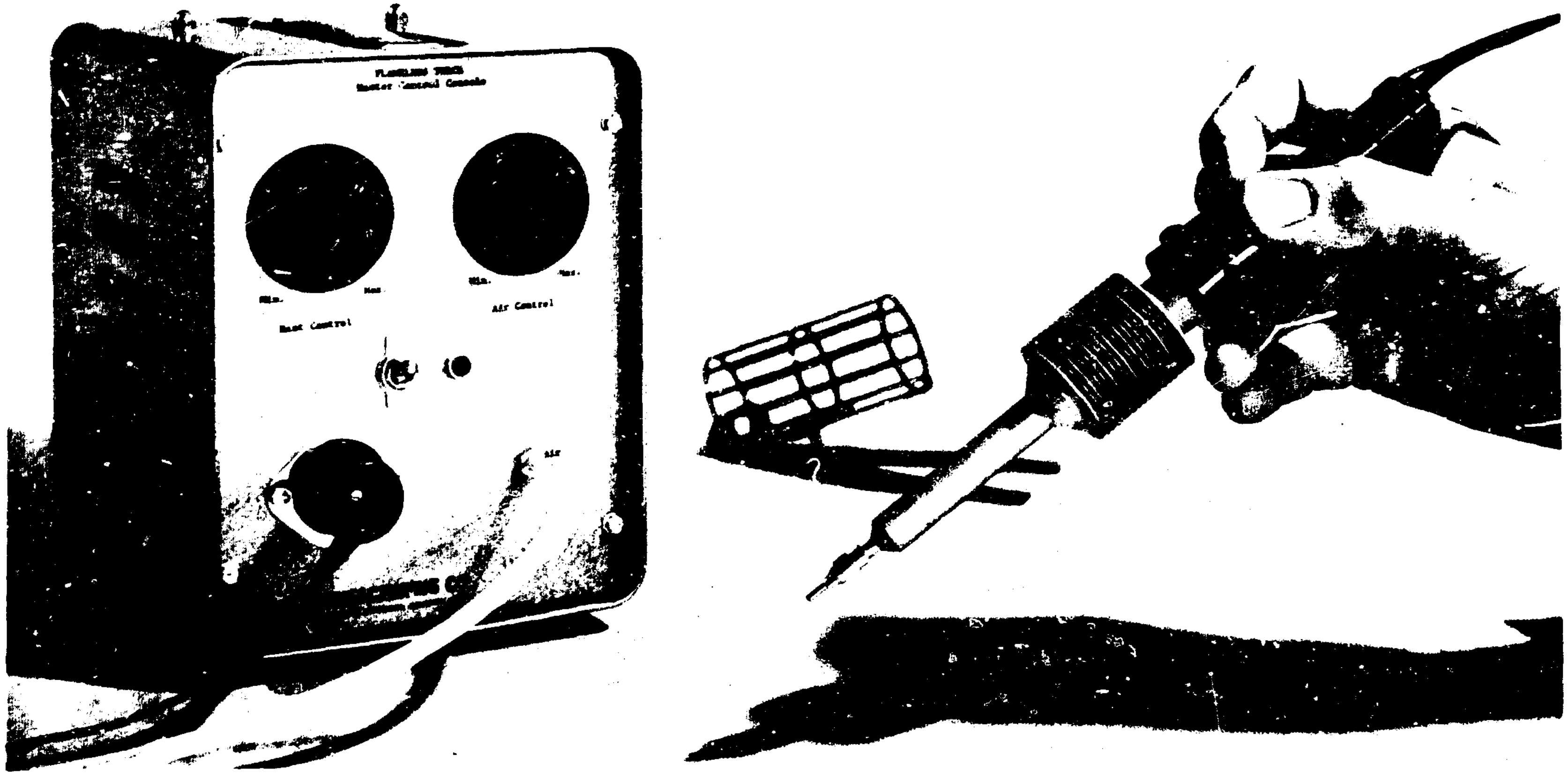

Figure 5. Flameless Torch (point is heat source).

III. MATERIALS AND DEFECTS.

Two laminated film composites, each from a different supplier, were used for the pouches. Both were suitable for thermoprocessed foods. The outer layers of the composites were 0.5-mil polyester (Mylar), the middle lamina were 0.35-mil aluminum foil, and the inner or heat-seal layer consisted of 3.0-mil modified polyolefin. The materials reacted identically to the infrared scanning procedure.

An olive-drab colored pigment has been applied to the inner surface of the polyester lamina. The color closely approximated No. 24087 of Federal Standard No. 595. An emissivity test on these materials showed a level of 0.97. Seal defects occur predominantly in the final, usually top, seal as schematically shown in Figure 6. This is the package opening through which product is put into the pouch, and is, therefore, very susceptible to product contamination. Furthermore, the stresses during the sealing of a bulging, filled pouch are variable and uncontrolled, and the ensuing seals tend, therefore, to have wrinkles and irregularities. The 4.5-inch top seal was the one scanned, and the one in which simulated defects were created.

There are no quantitative data on the minimum or even representative size of defects that might occur in package seals. Conceivably, a void or channel resulting from a wrinkle-causing action could be extremely small. Occluded matter could include small dust particles. It is, however, difficult to visualize the incidence of significant defects smaller than a 3.5-mil-diameter thread imbedded in the seal or the void created by withdrawing the thread. These two simulated defects are included in the list shown as Table 1. This table shows the simulated seal defects scanned and shows that, primarily, food components were used. The thread was used as a reproducible, definable defect. The thread diameter was measured prior to sealing, and it is possible that the differences among compressed, imbedded thread sizes are not proportional to the original differences in sizes.

Except for specific runs with production pouches or runs to determine the effect of different sealing methods, all seals were made with a Sentinel Model 12-12AS sealer, using a constant resistance, heated bar against a silicone rubber anvil (45 Durometer). Sealing conditions were 450° F., 1 second dwell time, and 40 psig pressure. The conditions used gave seals capable of withstanding thermoprocessing and subsequent handling.

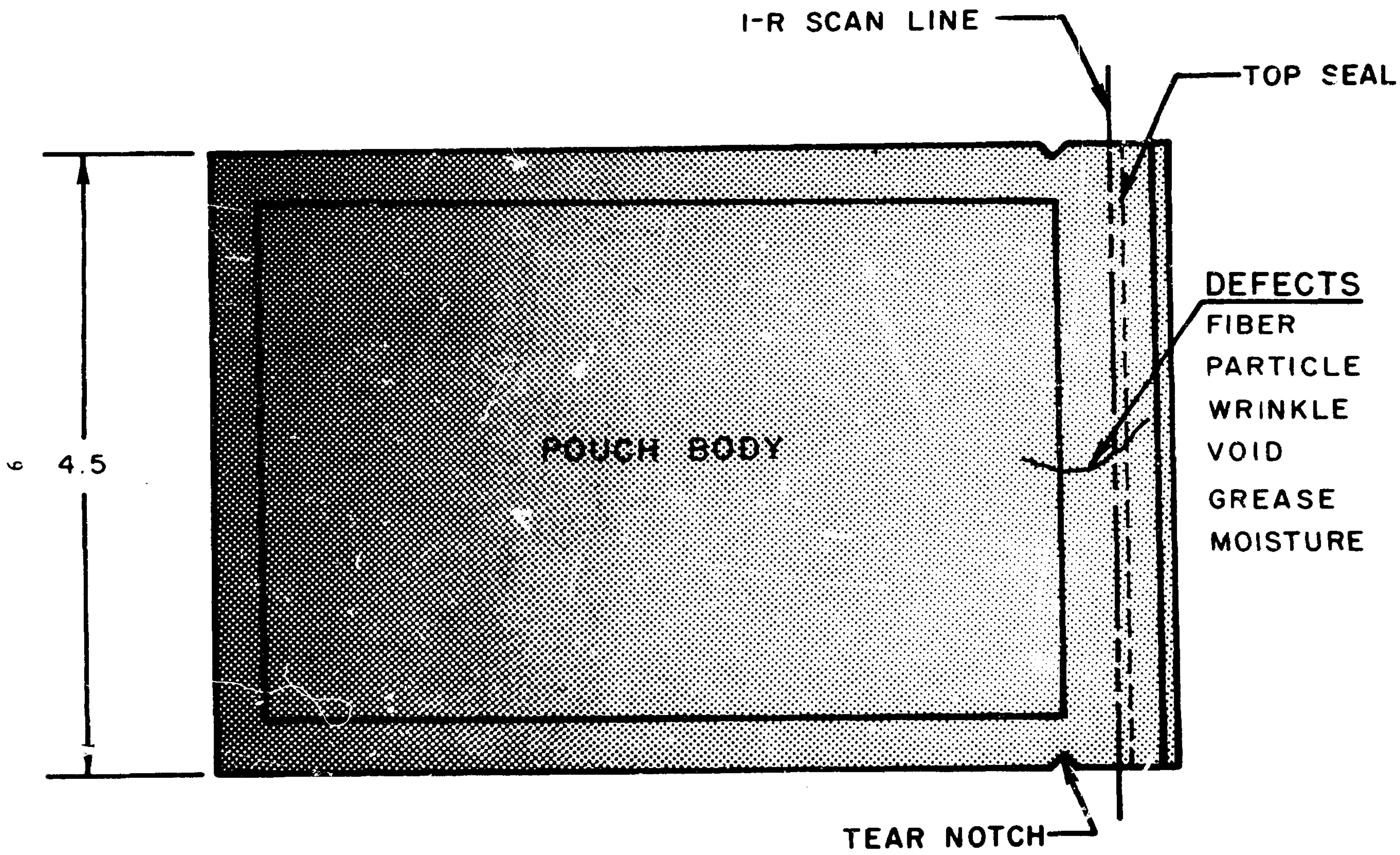

Figure 6. Schematic Drawing of Seal Defects.

Table I

Response of Infrared Microscope to Thermal Impedance
Caused by Simulated Seal Defects

Description	Size/Quantity	Response - Mv Replicate Samples	
		I	II
Pork Fibers	0.5 mg; 1.0 mg 1.0 mg	16 40	18
Celery Fiber	Single	26	
Pineapple Fiber	Single	17	30
Sugar Crystals	Single 3 each	14 18	
Potato Powder	0.5 mg 1.0 mg	7 14	14
Grease	Streaks	20	16
Moisture	Droplets	11	Off Scale
Wrinkle	1/16" Fold*	10	
Void	3.5 Mil** 26 Mil	9 Off Scale	8
Thread	3.5 Mil** 5.5 Mil 8.0 Mil	17 13 11	10

* 1/8" difference in length of seal surfaces.
** Nominal diameter of thread or wire prior to sealing.

IV. TEST PLAN AND CONSIDERATIONS.

Test runs primarily using the defects in Table 1 were made to determine:

1. The ability of the method to reproducibly detect defects caused by various types of contaminants or sources of voids and wrinkles.

2. The effect of defect size on the response.

3. The effect of different types of seals, including test production pouches.

4. Effect of defocusing to enlarge the target area, and, therefore, cover more of the seal area with a single scan.

4. Effect of variations in measurement conditions (limited optimization).

During the early screening runs, detection conditions (heat source temperature, scanning speeds (distances) were occasionally varied to improve detection. The results are, except for the optimization, best viewed on a comparative basis. Results are given as millivolts deflection from the background at the defect site. Temperature differences caused by the defects were approximately 1° C. With one pineapple fiber sample, however, a temperature difference of 7° C. was noted.

A critical consideration on interpretation of the curves and on the overall evaluation of the system is the nature and magnitude of massignable or random interferences which, in this instance, were the result of minor variations in emissivity, microscoping irregularities in the packaging materials and on the sealer hot bar surface, and stray air currents. The only controllable interference was stray air currents, and efforts were made to minimize these. The best control over background interference or "noise" was maintained during the optimization runs and the significance of interference can best be evaluated from those runs.

V. RESULTS AND DISCUSSION.

The objective of this study, as stated earlier, was to establish the feasibility of using an infrared scanning technique to detect defects in flexible package seal areas. The scope was held to determining the range of defects detectable, obtaining some degree of assurance that small defects could be found, and establishing the effects or trends that result from variations in measurement conditions. The results, hopefully, would motivate, ultimately, development of a production line method of test.

1. <u>Various types of defects</u>.

The initial group of runs was made under a single set of conditions to establish the ability of the method to detect whatever material might get trapped in the seal or whatever size void or wrinkle might be encountered. The results are shown in Table I as millivolts usable signal height. Figure 7 illustrates some of the response curves from the X-Y recorder. Scanning conditions, although constant, had not been optimized for these runs. For example, the initial peak for an 8-mil-diameter thread represented an 11-mv. response, while after optimization, to be discussed later, a 70-mv. response was possible. Therefore, the results in Table I and Figure 7 can best be judged as relative.

The smallest defects were 0.5 mg. of potato granules and dried pork fibers, 3.5-mil-diameter thread, and the void left by withdrawing the thread. Data from Table II and visual observations of curves as shown in Figure 7 indicate that these defects are detectable. The metal holder was not used on the initial screening runs and, therefore, the distances between heat source and package were not constant. This caused a sometimes variable slope to the background with some scans. An attempt was made to have the distances at the specific defect sites identical. The most difficult defect responses to interpret were those of grease and moisture. Response is best described as different from the control and irregular; however, there does not seem to be doubt that a defect or seal irregularity exists.

There was some variation in response to replicate samples. This was to be expected since natural fibers (pineapple) vary in size; the potato powder, pork fibers, and grease could have been lumped or spread out randomly during sealing. The thread was as reproducible as a defect as used; yet there were variations in response with replicates.

To check on reproducibility of the instrumentation, some scans of single samples were repeated. Figure 8 shows repeated scans of a 1/8-inch wrinkle and single sugar crystal. The ability of the system to respond similarly to repeated scanning of the same defect is considered good.

2. <u>Size of defect</u>.

Some simulated defects were created with different amounts or sizes of occluded material. There was no control over how the sealing operation affected the resulting defect in the seal itself. Table I shows pork fibers, sugar, potato powder, voids, and thread in at least two different sizes. Except for the thread, the larger amounts indicated

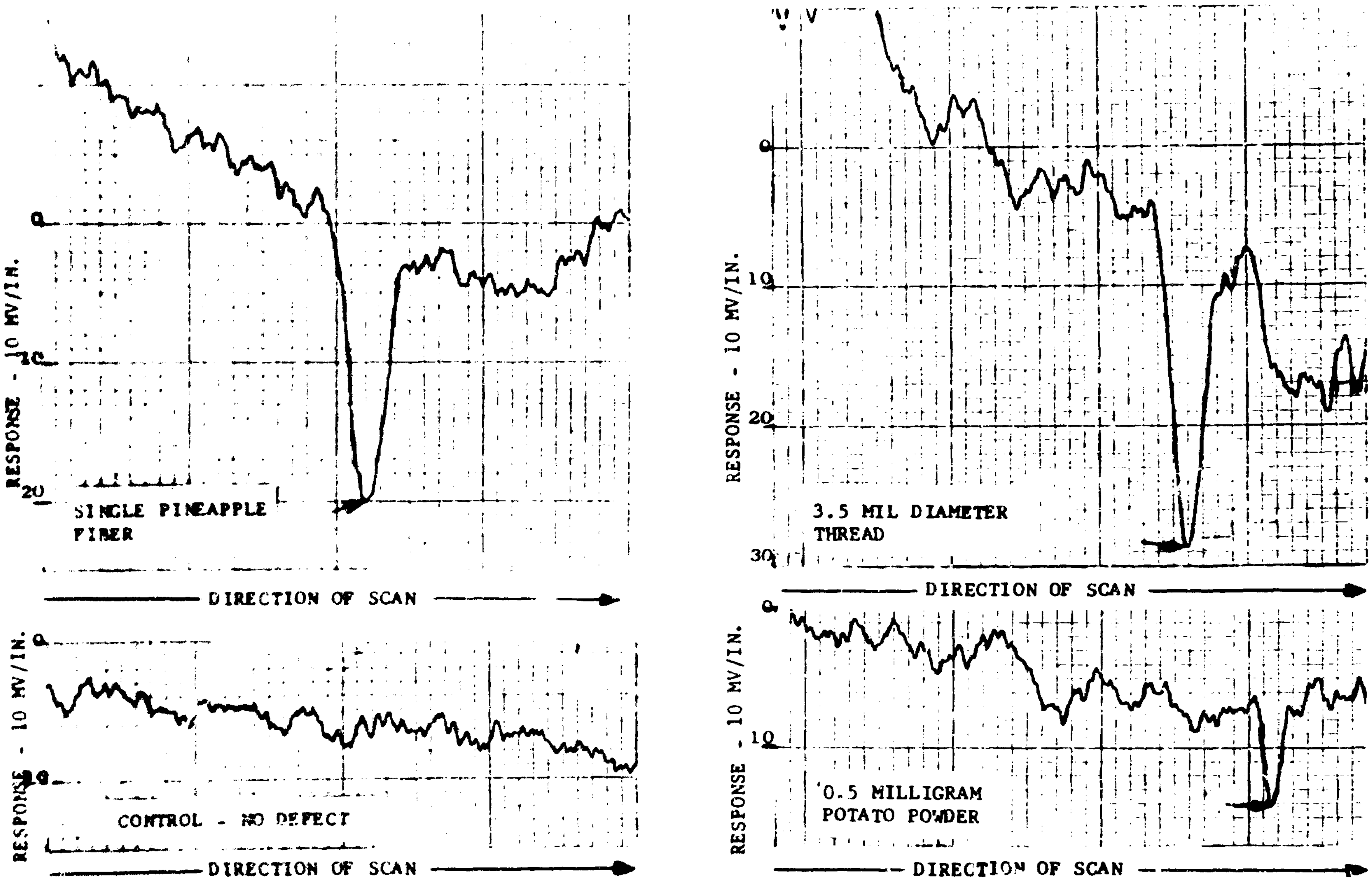

Figure 7a. Response to different types of defects.

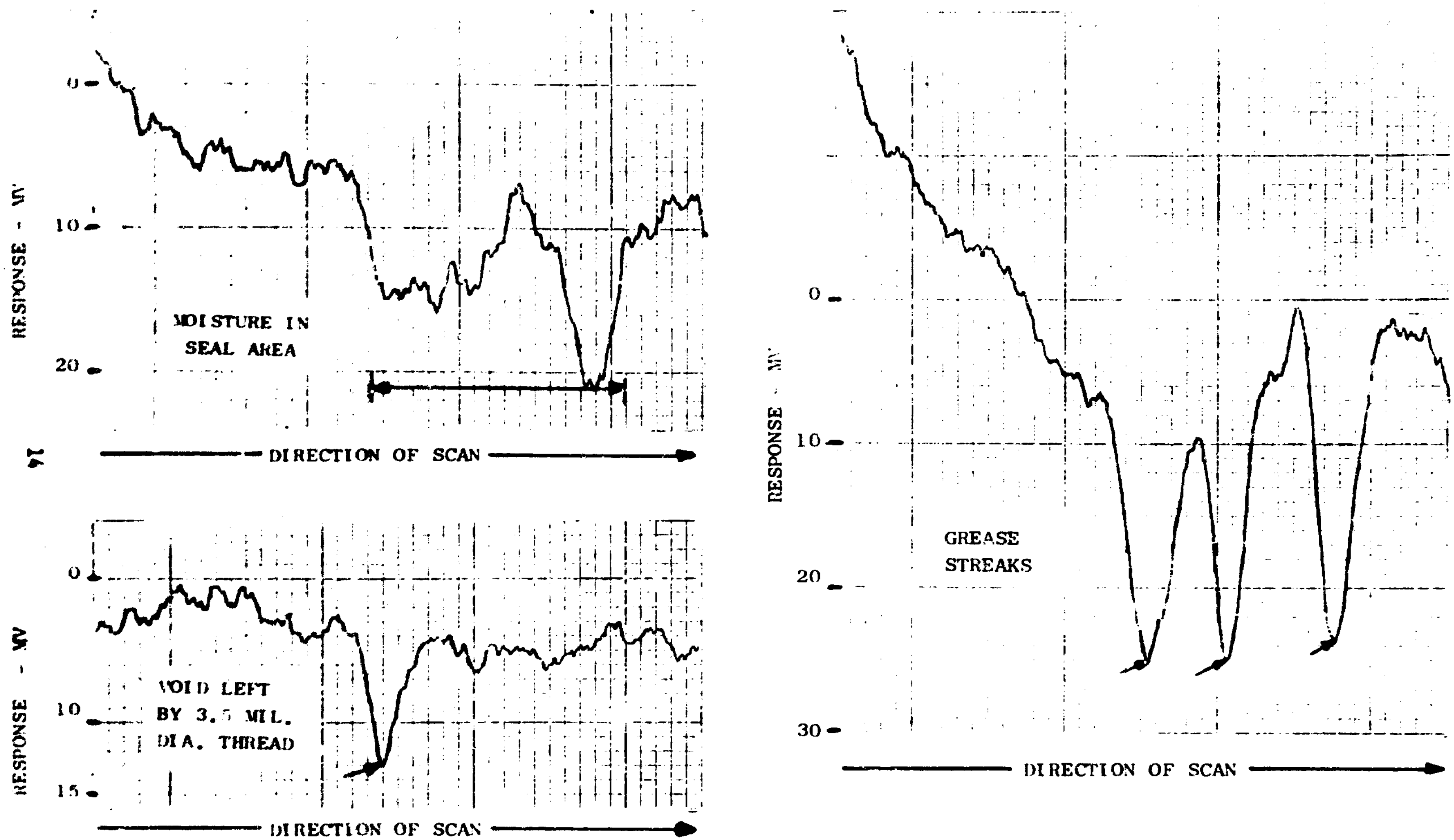

Figure 7b. Response to different types of defects.

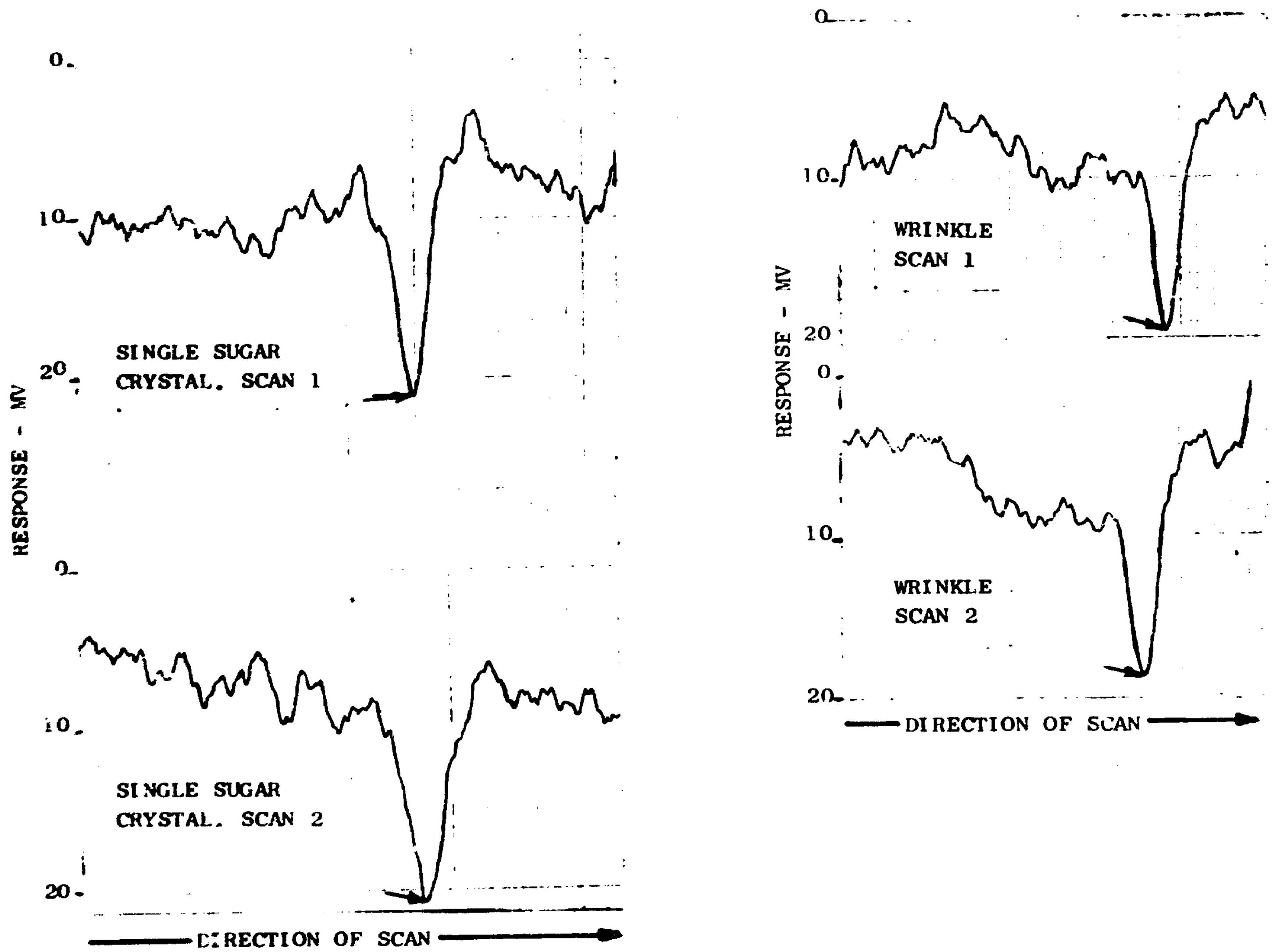

Figure 8. Repeated scans of single defects.

a tendency to greater response. The thread, for reasons not immediatley clear, but probably related to the broad limits of error for these early scans, showed lower responses as the size increased.

3. Various types of seals.

As stated earlier, most simulated seal defects for this study were made using a Sentinel Model 12-12AS sealer which produced commercial caliber seals. On test production runs of flexible packages of thermo-processed foods, the contractors used a similar technique - a hot bar against an unheated rubber anvil (Standard Packaging Corporation, Flex-Vac Model 6-9 Sealer or Model 6-10 Sealer). Figure 9 shows three scans of seals made on this commercial equipment. The chicken loaf was a production sample and indicated no defect and relatively even, low intensity background noise. Peeling the seal open and visual examination verified the absence of defects. The pork sausage sample was also from a test production run. A defect was indicated which, on closer examination, was found to be a small void existing in the area of a slight wrinkle. This was our first "unknown".

A third Flex-Vac seal was examined. This one was made using the Packaging Division's Model 6-9 Sealer and included an imbedded 3.5-mil-diameter thread. The positive result is shown in Figure 9, and, together with the other Flex-Vac Sealer curves, indicates that the infrared scanning method is applicable for this type of commercial seal.

Less promising results were obtained with another type of commercial seal. Figure 9 also shows a scan of a seal (containing a 3.5-mil-diameter thread) made with a 4-bar metal seal against a Viton rubber covered with Teflon Fiberglass cloth. Temperature of both elements was approximately 300° F. (149° C.); dwell time was 2.5 seconds; pressure is not known. Apparently, this type of sealer, with two heated elements, compressed the thread more than a single hot bar. There was no visual surface lump at the defect site, nor, on peeling back the two outer lamina and passing a pencil point with moderate pressure over the area, was there any detectable impediment. Pending further studies, it must be concluded that infrared scanning cannot detect such small defects in this type of seal.

Seals made ultrasonically were scanned with poor results. The knurled surfaces of these seals caused erratic, high intensity and magnitude background noise. The defect signal was indistinguishable from the background.

4. Defocusing.

At the working distance (target area to microscope objective when in focus) for the 15X lens and the Model RM-2B microscope, the spot size viewed for temperature is 0.0028-inch in diameter. This, in a scanning situation, becomes a narrow 0.0028-inch path going the length of the seal.

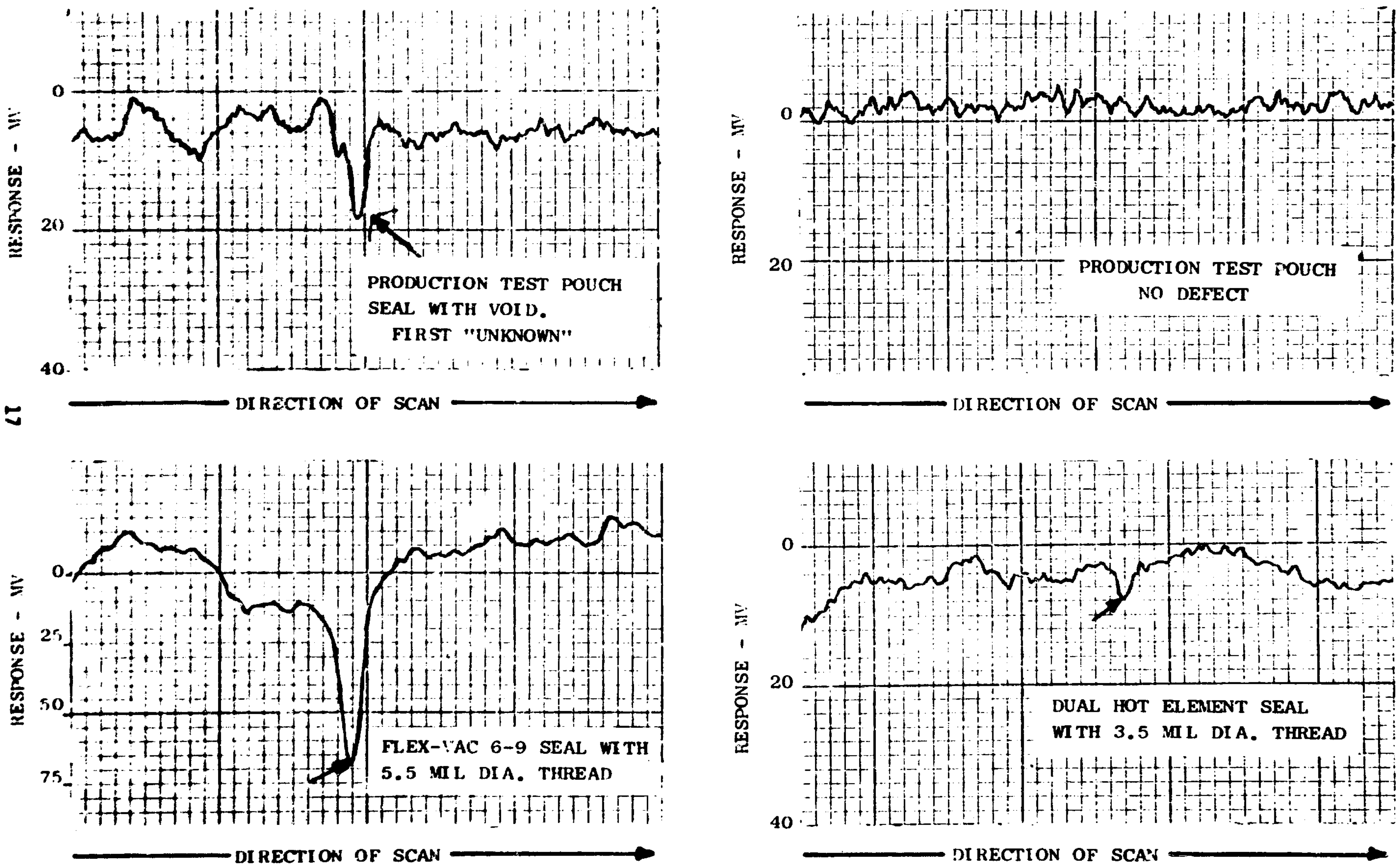

Figure 9. Scans of commercial seals.

The seal, based on present specifications, is at least 0.375-inch wide. The possibility exists that a single scan could miss a point defect or a fiber or other occluded material extending only partially into the seal area. This disadvantage could be overcome by multiple scanning or through viewing a wider area of the seal by purposely using the microscope out of focus.

The latter approach was tried using both a single sugar crystal as a point defect and void left by withdrawing a 3.5-mil-diameter thread from the seal. Figure 10 shows the results. The single sugar crystal, which was a more rigorous test since a smaller portion of each transitory field of view is the defect, showed itself as a significant signal at the optimum 0.0028-inch-diameter area. Enlarging the area to 0.03125-inch (1/32-inch) broadened the base of the signal response, but showed no lessening of signal magnitude and did indicate a smoothening out of background noise. At 0.25-inch, the defect signal lost some of its characteristic smoothness and some magnitude, but nevertheless showed a distinct response.

With the 3.5-mil void extending totally through seal area, the response was greater with a defocus to an area of 0.25-inch. Again, there was a smoothing out of background noise. Based on these runs, it appears possible to scan an area as wide as 0.25-inch without sacrificing significant sensitivity. With 0.375-inch-wide seals on a production line test procedure, alignment and indexing considerations made the practicability of scanning of a path wider than 0.25-inch (67% of the width) seem unlikely. A wide scan necessitates accurate alignment to prevent misinterpretation resulting from scans of non-seal area.

5. Optimization.

Relatively standard measurement conditions had been used during the earlier stages in establishing the sensitivity and applicability of the technique. No significant effort had been made to optimize the measurement variables. Therefore, two series of runs, using an imbedded, 8-mil-diameter nylon thread as a "standard" defect, were made to establish within the limits of the apparatus the effects of variations in measurement conditions.

The first series of runs consisted of first establishing the best distance by which the heat source should lead the infrared microscope, and then, using a 2^3 factorial design with two levels for each variable, determining the effect of the temperature of the heat source (air flow was held constant), the distance between the heat source and the package seal surface, and the scanning speed. The same standard defect was used for all the runs; however, assurance that the standard defect itself did not change was obtained by periodic (initial, midpoint, and final) rescanning under identical conditions. Since earlier repeated scanning

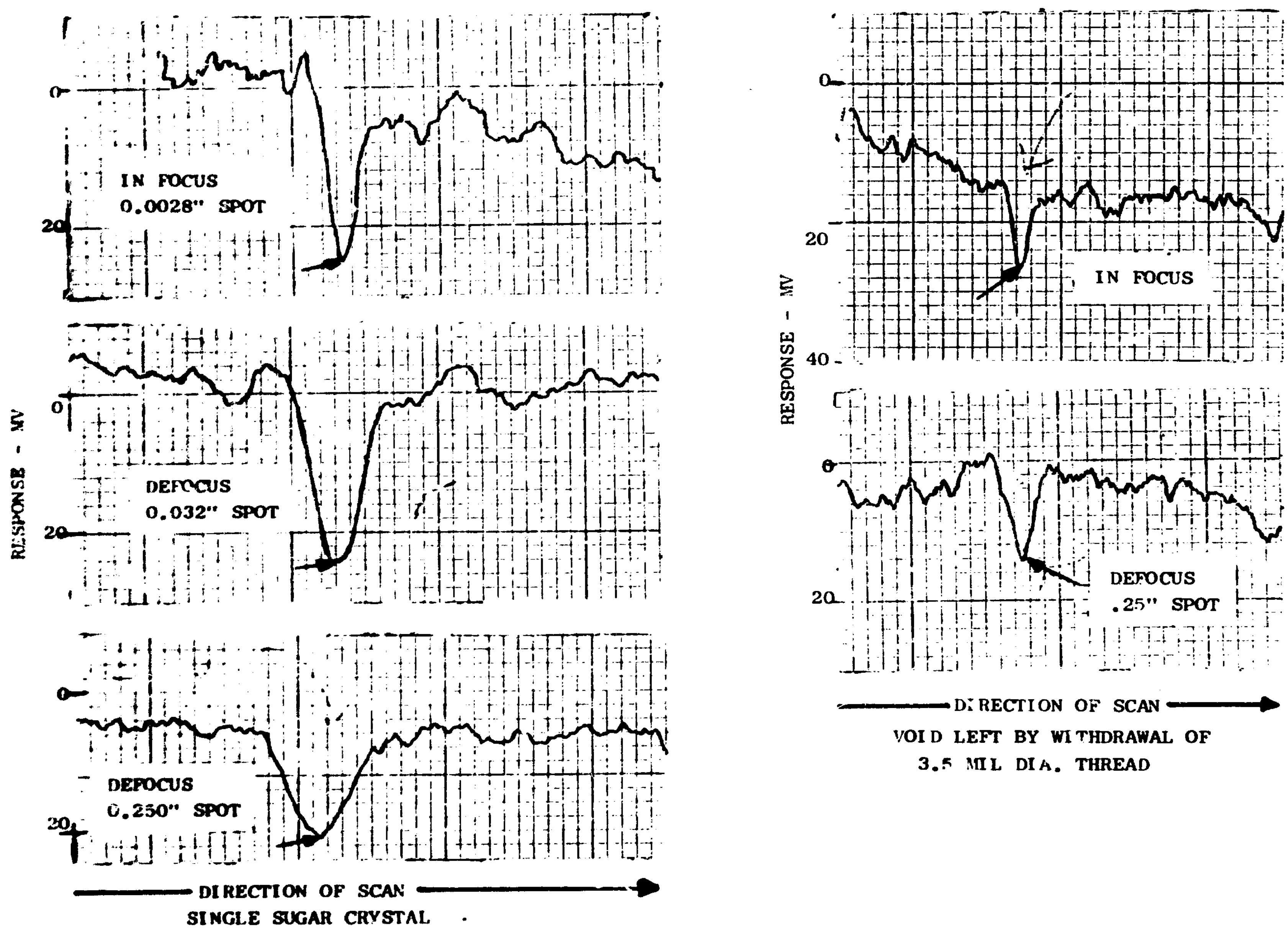

Figure 10. Effect of defocusing.

of a specific defect had indicated good reproducibility, and since there was the chance that the characteristics of the standard defect might change as the result of too many heatings, only a single run for each combination of variables was made.

Two heat source lead distances, 1/16-inch and 3/16-inch, were tried, and the shorter resulted in a better response. Any shorter lead distance would result in direct exposure of the microscope to the hot air stream when there was no package in between and would probably damage the microscope.

The results of the first series are summarized in Table II. The X-Y recorder response curve resulting from the best combination of variables is shown in Figure 11, upper portion, along with the response curve showing the least sensitivity (Figure 11, lower portion). Both appear adequate.

The data in Table II show defect signal magnitudes and maximum noise effects measured as millivolts deviation from a base line set at the highest point on the curve. A three-way analysis of variance was performed using the guideline of Anderson[5] to establish the effect and possible interactions of the usable signals (defect signal less noise). The analysis of variance table is given in Table III. This table indicates that only the distance between the heat source and the seal surface had a significant effect on the usable signal. The significance was at the 0.99 confidence level. Neither the temperature of the heat source nor the scanning speed within the ranges studied had any significant effect on the usable signal. This result is encouraging since indications are that close control of temperature may not be necessary and that conceivable, even faster scanning speeds are permissible. Although not significant, the F-value of the temperature effect is the second highest, and therefore temperature may be the second most important variable affecting the results. The interactions were not significant.

Background noise was variable. The only pertinent observation was that at the 0.25-inch, heat source-to-package distance the maximum noise effect at the faster scanning speed was three-fold that at the lower speed; the higher noise level did not, however, detract from the net sensitivity at the higher scanning speed.

The first series of optimization runs had indicated that a heat source-to-package distance of 0.25-inch was best. Although an even smaller distance might be more beneficial, it was decided to maintain that distance at a constant 0.25-inch and further vary the temperature of the heat source and the scanning speed for the second series. The recorder signal sensitivity was changed to 50 mv/inch.

The transversing pouch-holding carriage was not designed for speeds much above those already tried. To preclude irrevocable abuse of this mechanism, only two runs were made at the highest attainable speed.

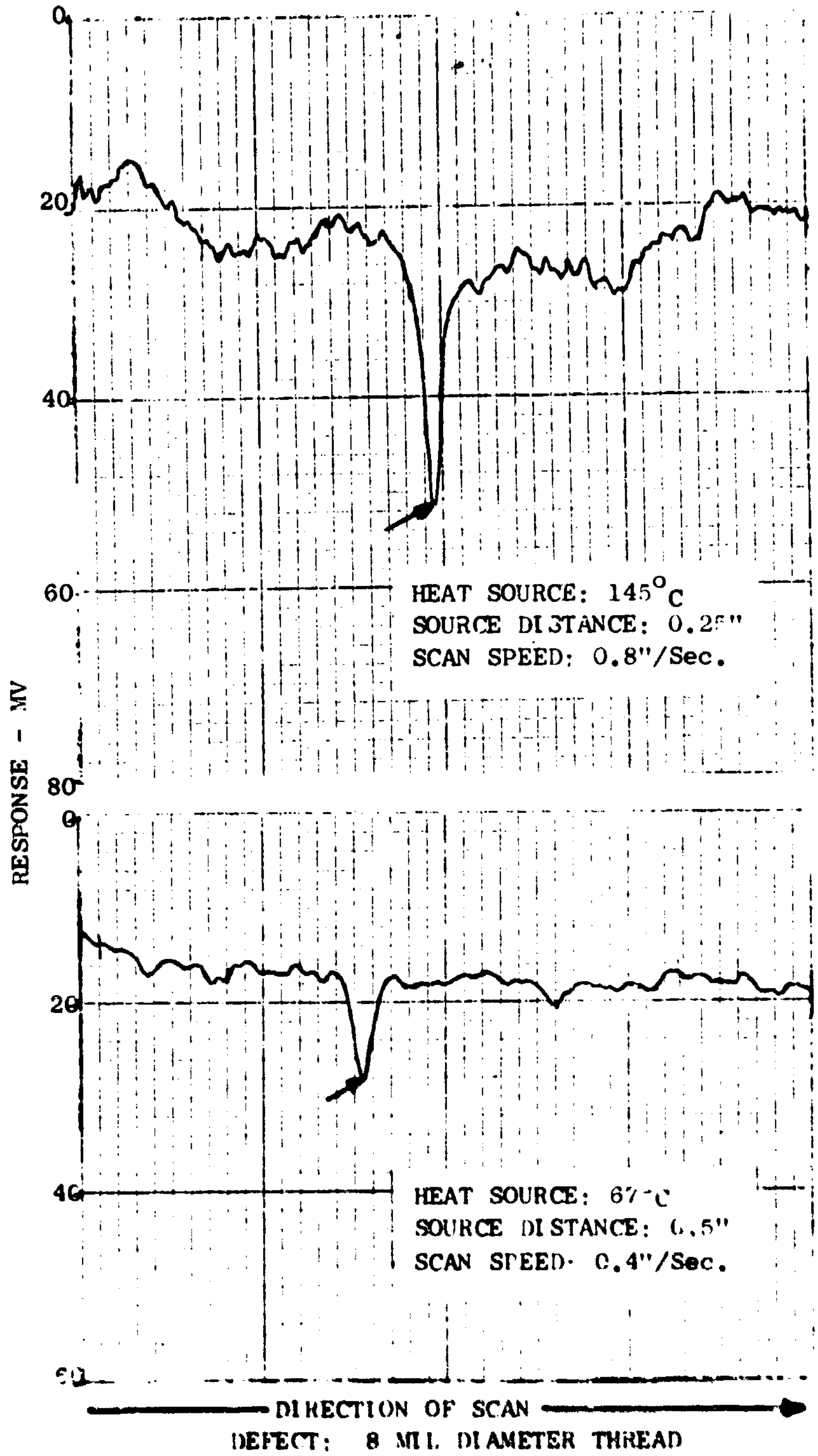

Figure 11. Effect of scanning variables.
First Series.

Table II.

Effect of Variations in Heat Source Distance, Seal Scanning Speeds and Heat Source Temperatures.

First Series.

Distance: Heat Source to Package, Inches*	0.25				0.5			
Seal Scanning Speed, Inches/Second	0.4		0.8		0.4		0.8	
Heat Sources Temperature, ° C.	67	145	67	145	67	145	67	145
Defect Signal, Mv**	20	22	26	34	14	22	14	15
Maximum Noise Effect, Mv.	4	3	10	10	6	12	8	7
Useable Signal, Mv***	16	19	16	24	8	10	6	8

* X-Y recorder time sweep: 1 inch/second.
** Recorder signal sensitivity: 20 Mv/inch
*** Useable signal = defect signal less maximum noise effect.

Table III.

First Optimization Series - Analysis of Variance.

	Degrees of Freedom	Sum of Squares	Mean Square	Test Statistic F.
Column*	1	231.12	231.12	22.55
Row**	1	0.12	0.12	0.012
Layer***	1	28.12	28.12	2.74
C X R	1	10.13	10.13	0.99
C X L	1	6.13	6.13	0.60
R X L	1	3.13	3.13	0.305
Error	4	40.5	10.25	-----

$F(1, 4) = 7.71$; $F(1, 4) = 21.20$

* Column = Distance between heat source and seal surface.
** Row = Scanning speed.
*** Layer = Temperature of point heat source.

The results of the second series of optimization runs are given in Table IV. Figure 12 shows the response curves for a heat source temperature of 145° C. and both scanning speeds. It should be noted that the X-Y plots in Figure 12 for the two seal-scanning speeds were made at different recorder time sweeps, and this undoubtedly affected the magnitude of the recorded signal. It is evident from the data that variations in heat source temperature, at least within the ranges investigated, did not greatly or predictably affect the usable signal at either scanning speed. A direct comparison of scanning speeds would not be valid because of the differing time sweeps; however, the data and visual examination of the curves indicate that the faster speed gave excellent results, and that, in all probability, still faster scans could be made.

The two series of optimization runs revealed that the distance the heat source and seal surface significantly affected the results, and that a 0.25-inch distance was better than 0.5-inch. The temperature of the heat source can vary from 127° to 187° C. without effect. A scanning speed of 1.14-inches of seal/second is feasible, and faster scans should be tried.

VI. CONCLUSIONS.

The study revealed that the use of infrared radiometric measurement of thermal impedance for nondestructive detection of defects in flexible package seals is technically feasible, but with some qualification.

1. On the positive side, conclusions were:

a. The method was able to detect defects resulting from a variety of causes, including grease, moisture, occluded food fibers, and particles, voids, and wrinkles.

b. Defects as small as 0.5 mg of freeze-dried meat fibers, single crystals of sugar, and voids left by withdrawing a 3.5-mil-diameter thread were detected. It is difficult to visualize any significant incidence of defects smaller than these during commercial operations. Sensitivity, therefore, seems adequate.

c. Defects in commercial caliber, hot bar seals made by laboratory sealers and at least one type of production line sealer were detected. These seals are the type suitable for flexible packages of thermoprocessed foods.

d. A defect signal of 50 to 70 mv. above the maximum background noise (a signal to noise ratio of 3.3 to 1) could be obtained, and

Table IV.

Effect of Variations in Heat Source Temperature and Seal Scanning Speeds.

Second Series.

Scanning Speed - inches/second*	0.8					1.14	
Temperature of Heat Source - ° C.	127	145	165	175	187	145	175
Defect Signal - Mv.**	90	85	70	85	95	65	65
Maximum Noise Effect - Mv.	20	15	25	25	35	15	15
Useable Signal - Mv.***	70	70	45	60	60	50	50

* The time sweeps of the recorder differed for the two scanning speeds as follows:
0.8 inches/second seal scan: 1 inch/second sweep,
1.14 inches/second seal scan: 2 inches/second sweep.
** Recorder signal sensitivity: 50 mv/inch.
*** Useable signal = defect signal less maximum noise effect.

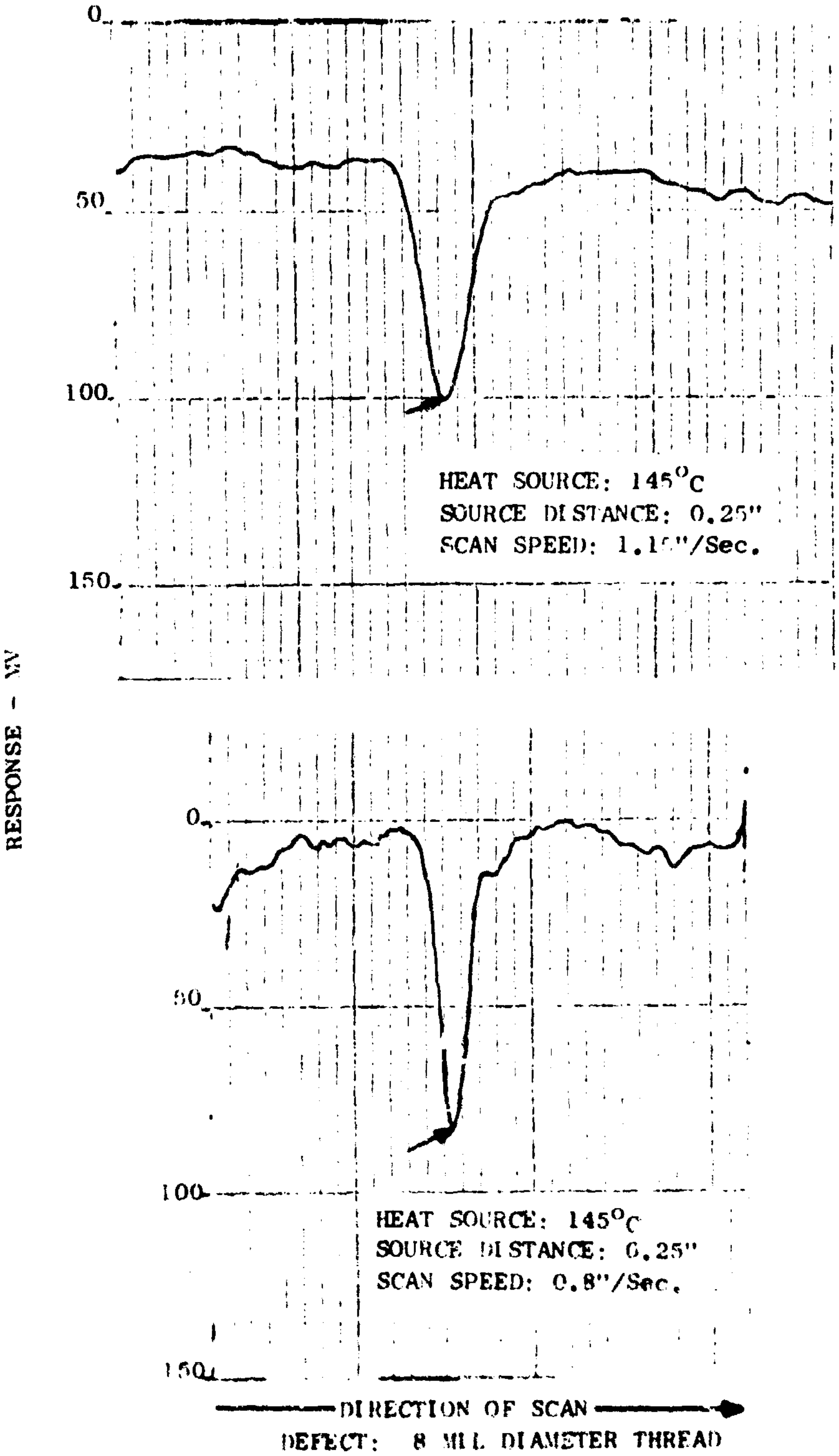

Figure 12. Effect of scanning variables.
Series II.

interpretation of results, in general, could be made easily. Commercial seals did not cause inordinate background noise.

e. Reproducibility, to give like scan results on repeats of a single sample and on replicate samples of the same type and size of defect, was good.

f. Defocusing to enlarge the field of view and permit a single scan to cover a larger portion of the total seal area did not, in a limited number of runs, lessen sensitivity.

g. Studies on operating variables revealed that the distance between the point heat source and the seal surface has significant effect on the signal, but that heat source temperature and scanning speed, within the ranges studied, had no significant effect. There were no significant interactions. A set of operating conditions can be listed.

(1) Heat source to microscope lead distance: 1/16-inch.

(2) Distance from heat source to package seal surface: 1/4-inch.

(3) Scanning speed: 1.14 inches/second, possibly faster.

(4) Heat source temperature: 145° to 175° C. at air flow of 2 cu. ft./hr.

2. On the negative side, the study indicated that the I-R scanning method did not detect a small defect in a commercial type seal made by two opposing heated elements with a long dwell time, and that scanning of ultrasonic seals is not feasible.

Further investigations and refinements should be pursued.

VII. RECOMMENDATIONS.

Since the method is technically feasible for seals of the type encountered with packages of thermoprocessed foods, an obvious recommendation is more studies leading, eventually, to a production line method of test. Examples are:

1. Investigations on the incidence and significance of minute defects relative to the integrity of seals made by various sealing techniques. Such questions as "Does a speck, occluded in the seal but totally surrounded by a good bond, lower seal integrity?", and "If a dual opposing hot-element sealer is used as opposed to a single, hot bar, does a small occluded fiber still present a problem?" remain to be answered.

2. Further variations in scanning conditions especially towards increasing the scanning speed. Included could be efforts to reduce background noise by shielding to eliminate stray air currents and/or gentle, uniform preheating.

3. Mechanical design effort to establish concepts and a way of using the method on a production-line basis.

VIII. LITERATURE CITED.

1. Szczeblowski, J. W. and Rubinate, F. J., Integrity of food packages, Modern Packaging 38, (10), 131, 1965.

2. McIntosh, R. B., Jr. and Yoder, J. R., An infrared radiometric microscope for non-destructive testing integrated circuits. Theory, Application and Instrumentation for Infrared Non-Destructive Testing, Barnes Engineering Company, Stamford, Connecticut, 1966.

3. Stemfill, D. F. and Yoder, J. R., Infrared inspection of semiconductors. Paper presented to the Symposium on Manufacturing In-Process Control and Measuring Techniques for Semiconductors, Phoenix, Arizona, March 9-11, 1966.

4. Infrared microscope Model RM-2B. Bulletin 12-911. Barnes Engineering Company, Stamford, Connecticut, 1967, 4 pp.

5. Anderson, L. B., Factorial design of experiments. Chemical Engineering 70, (18), 99-104, 1963.

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13. ABSTRACT

Infrared radiometry, whereby changes in heat conduction through the seal thickness and the resulting effect on the thermal radiation characteristics of the opposing seal surface are measured by an infrared radiometric microscope, has been used to detect significant defects in flexible package seals. Sample manipulation techniques and measurement parameters have been established to the extent that occluded matter such as single sugar crystals, 0.5-milligram amounts of meat fibers, single fruit and vegetable fibers and traces of moisture, as well as significant seal wrinkles, and the presence of small voids (90 to 100 microns in diameter) can be positively detected.

The method is applicable to laboratory and commercial-type seals formed by a hot bar against an unheated rubber anvil. Poor results were obtained with ultrasonic seals and inconclusive results with dual-heated element sealers.

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	ROLE	WT	ROLE	WT	ROLE	WT
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Seals	9					
Contrainers	9					
Flexible	0					
Microscopes	10					
Infrared radiometry	10					
Preservation	4					
Food	4					